SECTION 206 Flood Plain Management Services

After-Action Report on the Local Flood Warning System

for the

Wepawaug River in Milford, Connecticut

Prepared by

Basin Management Division, Planning Directorate

For

Chief, Flood Plain Management Services, Washington, D.C.

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US Army Corps
of Engineers
New England Division

Abstract

The purposes of this project were to develop a flood warning and response system for a specific floodplain area, and to identify a role for the Flood Plain Management Services (FPMS) program as it pertains to such systems. The purpose of a flood warning and response system is to warn floodplain occupants of an impending flood so that evacuation and/or mitigating measures may be taken prior to its arrival. A flood warning and response system consists of four critical components: flood threat recognition, forecast and warning message preparation, message dissemination, and warning response. A flood-specific preparedness plan, addressing how the four components work together in a flood scenario, must be formulated by the local community well in advance of a flood in order to maximize the benefits from the local flood warning and response system.

At the request of the State of Connecticut's Department of Environmental Protection (DEP), the Army Corps of Engineers provided technical and other assistance to the state in its effort in implementing a local flood warning system to warn residents of the City of Milford, Connecticut, of potential flooding of the Wepawaug River. The flood warning system proposed is a relatively high technology system, with precipitation and river stage gages in the Wepawaug River drainage basin remotely-transmitting data via line-of-site radio waves to a base station receiver/computer equipped with software to display and analyze the remotely-sent data. Milford's local flood warning system will be integrated into the State of Connecticut's existing Automated Statewide Evaluation in Real Time (ASERT) system. The ASERT system is a state-wide network of precipitation, river stage, and weather station gages that remotely-report to base station computers located at the DEP office in Hartford, Connecticut, and the National Weather Service's Northeast River Forecast Center (RFC) in Bloomfield, Connecticut. The ASERT system gage data is transmitted to the DEP and RFC computers via line-of-site radio waves, with radio wave repeaters sometimes required to relay the signals around mountains and other obstacles. The ASERT system has two primary purposes: to facilitate an early state and municipal response to potential flood events; and, to collect data for the state's meteorological and climatological data base. The ASERT system enables event response through the state and NWS monitoring and detection of weather events in the state capable of producing floods, and the subsequent issuance of warnings of potential flood events to municipalities with and without local flood warning systems. Municipalities with local flood warning systems may receive numeric site-specific warnings from NWS, while those without local systems may receive only general warnings of the potential for flooding. It is anticipated that up to 25 local flood warning systems will eventually tie into the ASERT system.

The state DEP proposed to sponsor Milford's local flood warning system, fund the majority of the hardware cost, install the system, train the local users, and maintain the remote-reporting hardware. Milford's system would become the fifth local flood warning system tied into the ASERT system. The Corps role in this project consisted primarily of providing advice and assistance to the state concerning the local system and of trying to clearly identify institutional roles to insure the system's success.

The state's proposal of a local flood warning system was accepted by the City of Milford, and the proposed system will apparently be deployed late in 1991. Hardware of the local system will consist of two precipitation gages, a combination lake level/precipitation gage (existing), and a combination river stage/precipitation gage located in the 19.8 square mile Wepawaug River basin, with all gages remotely-reporting to a base station computer located in Milford, as well as to the ASERT system's base station computers.

This report describes the four components of a flood warning and response system, the need for flood warning in Milford, the proposed system's hardware, the Corps' observation of the roles of the various agencies in flood warning, and the various factors that may lead to the local system's success or its failure are discussed.

After-Action Report on the Wepawaug River Flood Warning and Response Project for Milford, Connecticut

FIGURES

TABLES

PLATES

1. BACKGROUND

a. Authority

Authority for U.S. Army Corps of Engineers participation in this effort is sanctioned by Section 206 of the 1960 Flood Control Act (Public Law 86-645) which states:

> "...The Secretary of the Army, through the Chief of Engineers, Department of the Army, is hereby authorized to compile and disseminate information on floods and flood damages, including identification of areas subject to inundation by floods of various magnitudes and frequencies, and general criteria for guidance in the use of flood plain areas and to provide engineering advice to local interests for their use in planning to ameliorate the flood hazard..."

b. Purpose and Scope

This study is one of four studies being conducted in Corps Flood Plain Management Services (FPMS) offices nationwide. Each of the studies has the two following purposes:

1. to develop a flood warning and response system for a specific floodplain area by providing technical and other assistance; and,

2. to identify the appropriate role for the Corps Flood Plain Management Services program pertaining to flood warning.

Each study was to include the development of hydrologic and hydraulic data for a selected floodplain area, the identification of the flood hazard areas, the design and installation of an automated data-collection and transmission system, and the formulation of an appropriate flood preparedness plan. This report documents the effort of the New England Division Corps of Engineers to assist in the implementation of a flood warning and response system for the Wepawaug River floodplain in Milford, Connecticut, and identifies a suggested FPMS role in flood warning and preparedness.

c. Selection of Study Area

The New England Division's investigation of a local flood warning system for the Wepawaug River floodplain in Milford, Connecticut was requested by the State of Connecticut's Department of Environmental Protection (DEP). The DEP is the lead entity in Connecticut's Committee on Automated Flood Warning, a multi-agency task force formed in direct response to the disastrous statewide floods of June 1982. The Committee has been responsible for the design and implementation of a Connecticut-wide network of remote-reporting gages known as the Automated Statewide Evaluation in Real Time (ASERT) system. The ASERT gages are monitored by state and National Weather Service personnel for the purposes of facilitating an early state and municipal response to flood events. Another use of the ASERT system is for the collection of data for the state's meteorological and climatological data base. Ultimately, the state envisions that up to twenty-five local flood warning systems will link to the ASERT system. At present, four local flood warning systems have been linked to the state system.

The Committee had identified nearly 25 sites likely to benefit with specific and timely river stage flood forecasts via local flood warning systems. One of the identified sites, the Wepawaug River floodplain area of Milford, Connecticut, was prioritized for consideration by the state because of the extensive and highly concentrated nature of the flood damages it received during the June 1982 flood. When made aware of the Corps desire to assist a local sponsor in implementing a local flood warning system, the State of Connecticut solicited Corps assistance in developing a local flood warning system for Milford with the state as sponsor of the project.

d. Study Area Description

The City of Milford, Connecticut, located in south-central Connecticut adjacent to Long Island Sound, is primarily a commercial and manufacturing center serving the several cities that surround it (see Figure 1, Location Map). The City of Milford covers an area of 23.5 square miles and has a population of 52,100. Three significant rivers flow through the city or along its boundary: the Housatonic River, the Wepawaug River, and the Indian River.

The Wepawaug River originates in the Town of Woodbridge, Connecticut and flows south through Orange and then Milford where it discharges into Long Island Sound. The drainage area of the Wepawaug River basin is 19.8 square miles at its mouth (see Plate 1, Watershed Map). The Wepawaug River basin is elongated in shape, with a length of approximately 11.5 miles and maximum width of about 2.7 miles. The Wepawaug River has only one significant tributary, Race Brook, with a drainage area of 4.2 square miles. The fall of the river is about 460 feet in its 11.5 mile course, of which nearly 60 feet occurs in the 3 miles through Milford. The 16-foot high New Haven Avenue dam separates the river from the tidal influence of Long Island Sound.

At the study area's uppermost point, located approximately 1800 feet upstream from interstate I-95 in Milford, the Wepawaug River has a drainage area of approximately 18 square miles. The study area extends approximately 1.5 miles from this point down to Milford Harbor. Properties affected by Wepawaug River flooding in the upper reach of the study area include residential development and a major industrial facility. Those affected by flooding in the lower study reach consist of many commercial buildings, and a few public buildings. The many stone arch bridges, the City Hall Dam and some open space along the Wepawaug River help to create a scenic "green belt" park environment in the lower study reach.

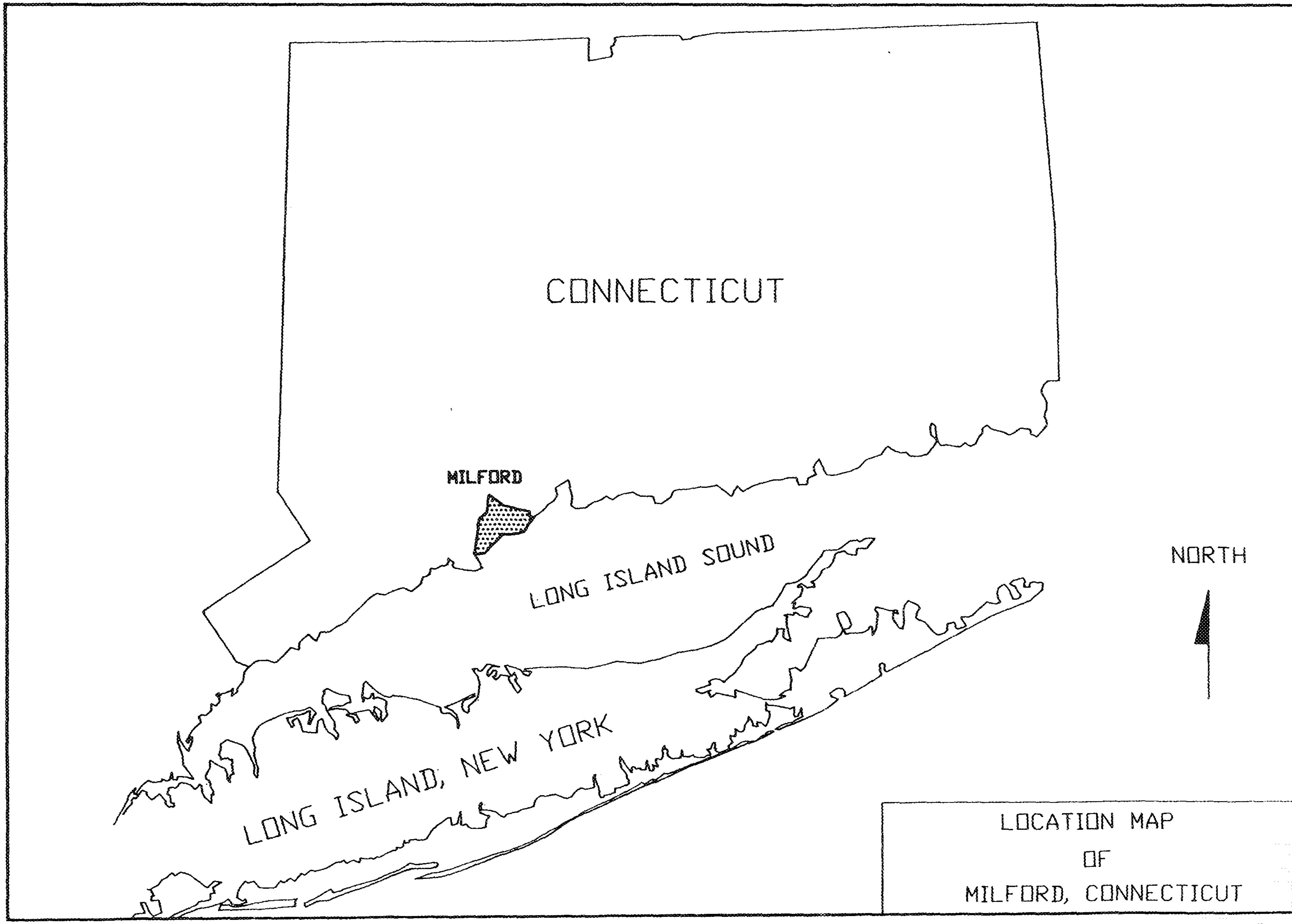
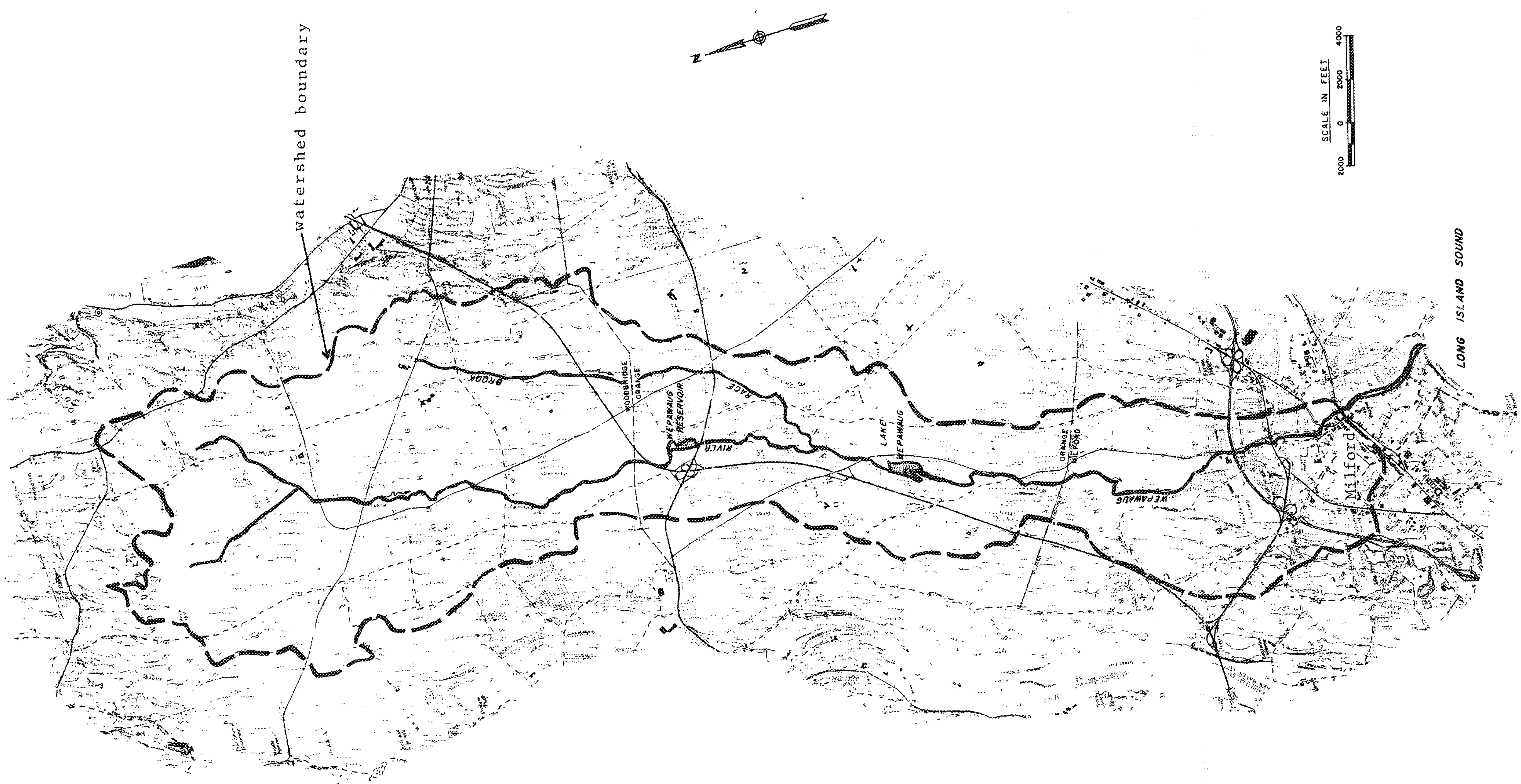

CONNECTICUT
MILFORD
LONG ISLAND SOUND
LONG ISLAND, NEW YORK
NORTH
LOCATION MAP
OF
MILFORD, CONNECTICUT

FIGURE 1

CORPS OF ENGINEERS

U. S. ARMY



REVISION	DATE	DESCRIPTION	BY

DES. BY | DR. BY | CK. BY

SUBMITTED:

CHIEF, CIVIL ENGR. SECTION

APPROVAL RECOMMENDED:

CHIEF, DESIGN BRANCH

REVIEWED:

PROJECT MANAGER

APPROVAL RECOMMENDED:

WEPAWAUG RIVER BASIN

WEPAWAUG RIVER, CT.

WATERSHED MAP

HYDRO. ENG. SECT.

APPROVED

DATE

CHIEF, ENGINEERING DIVISION

SCALE

SPEC. NO.

DRAWING NUMBER

SHEET

PLATE I

e. Prior Investigations

In a September 1985 Detailed Project Report (Reference 10), the Corps of Engineers recommended construction of a dike and channel widening to protect a small portion of the Wepawaug River study reach upstream from interstate I-95. This structural measure was not implemented due to lack of local support.

In an April 1988 report (Reference 3) prepared for the City of Milford, a private engineering firm had examined alternative damage-reduction measures for the same area of floodplain studied by the Corps. The report concluded that only the Corps-recommended structural solution was feasible for significant damage reduction. The report did, however, recommend pursuit of an early flood warning system.

2. FLOOD WARNING AND RESPONSE SYSTEMS

a. Components

There are four major components of a local flood warning and response system: 1. flood threat recognition; 2. flood forecasting and warning message creation; 3. warning message dissemination; and, 4. flood warning response.

The flood threat recognition component of a flood warning and response system includes the awareness by officials of the near-term possibility of a flood at the subject area. There are several ways a flood threat can be recognized including the detection of a rapid rise in river stage, or the movement of a storm towards the subject drainage basin, etc. In an automated local flood warning system, sometimes referred to as ALERT (Automated Local Evaluation in Real Time) system, the possibility of a flood typically is noted by the sounding of an alarm at a base station computer that monitors the remote precipitation and/or river stage gages in the drainage basin; the alarm is sounded when a pre-set threshold value, or rate of rise, is exceeded at one or more of the gages. Figure 2 shows a simplified typical ALERT configuration.

The flood forecasting and warning message creation component of a flood warning and response system includes the analysis of the remotely-reported and other available data to forecast the river stage expected at the damage area. The warning message communicating this forecast must be carefully tailored to the intended audience and to what is expected of them. The message may include the degree of certainty associated with the forecast.

The warning message dissemination component of a flood warning and response system includes the method(s) that the message will be issued to the public. Various methods of message dissemination include the use of sirens, radios, televisions, house-to-house knocking on doors, etc.

The response component of a flood warning and response system is the part of the system where benefits are received, and therefore considerable attention should be given to this aspect. People receiving the warning may respond by evacuating the floodplain, moving stock and contents out of the expected path of the floodwaters, implementing various non-structural floodproofing measures, ignoring the warning, etc.

b. Agencies Involved

In Connecticut, the roles of the various agencies in support of local flood warning were well established prior to the state's request for Corps assistance in implementing a flood warning system for Milford. Several agencies play an active role in system development and maintenance.

Connecticut's Committee on Automated Flood Warning, a multi-agency task force of nearly ten federal, state and local organizations and private utilities, was formed in response to the disastrous statewide floods of June 1982. The Committee was responsible for the design and implementation of Connecticut's Automated Statewide Evaluation in Real Time (ASERT) network of remote-reporting precipitation and weather station gages, radio wave repeaters, and signal-receiving base station computers. The ASERT system is discussed at length in Section 2d. The Committee also supports the implementation and use of local (municipal) flood warning systems, commonly known as Automated Local Evaluation in Real Time (ALERT) systems, that will link to the ASERT system.

The Committee on Automated Flood Warning brings the various agencies together in its meetings held approximately once a month. The meetings primarily center on ASERT hardware issues such as maintenance problems or problems with radio signal reception. This may be due to the fact that when the Committee was first formed, there was no full-time personnel in the state capable of keeping the remote-reporting hardware operating properly. This capability changed with the fairly recent state hiring of a technically competent person to maintain, calibrate, and upgrade the system hardware.

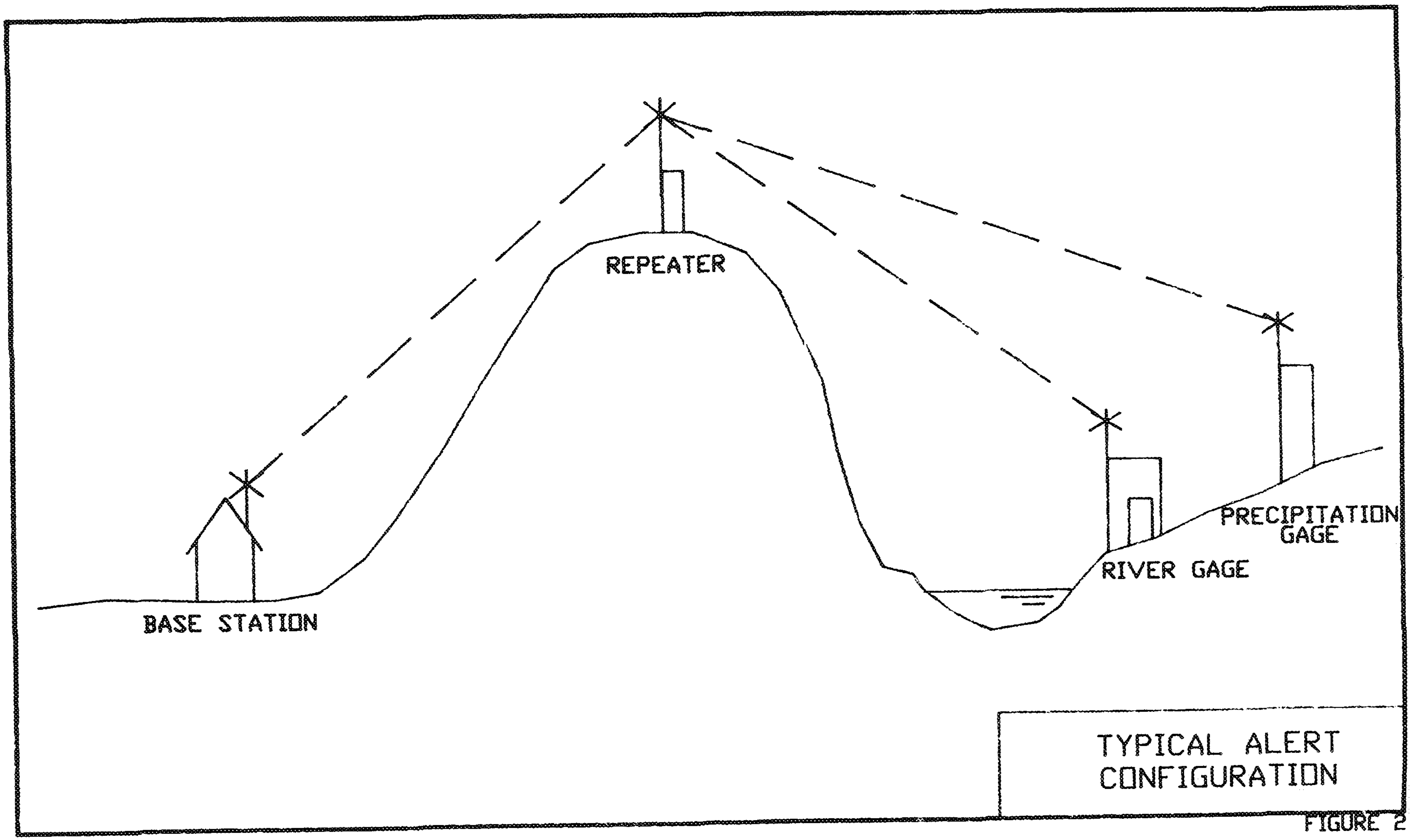
The primary agencies in the Committee are the State of Connecticut Department of Environmental Protection's (DEP) Water Resources Unit, the state Office of Emergency Management, the U.S. Soil Conservation Service (SCS), and the National Weather Service. The ASERT system was initially funded by the SCS and the DEP.

The <u>State of Connecticut DEP</u> has three full-time personnel and a program administrator associated with the ASERT system. One of the full-time personnel is responsible for the day-to-day operation of the system and coordination of system expansion; the other two are responsible for the maintenance of all of its remote-reporting gages, and the upgrading of the system.

The Federal agency with the responsibility of flood forecast issuance is the <u>National Weather Service</u> (NWS). The Northeast River Forecast Center (RFC) located in Bloomfield, Connecticut, the Weather Service Office (WSO) located at Bradley International Airport in Windsor Locks, Connecticut, and the WSO at Bridgeport, Connecticut, are the offices of NWS that prepare and issue the flood forecasts for Connecticut. The role of the NWS in support of local flood warning systems is discussed in Section 2e.

The <u>U.S. Soil Conservation Service</u> (SCS) has been a major participant in automated flood warning in Connecticut. Besides providing technical assistance and funding for the ASERT system's initial deployment, the SCS has been actively conducting building-by-building flood audits in areas with local flood warning systems. The flood audits are building-specific emergency response plans that provide floodplain occupants the means to translate the river stage forecast into an appropriate response.

The <u>U.S. Army Corps of Engineers</u> New England Division (NED), although not a lead agency in the field of flood warning, has implemented two flood warning systems in conjunction with NWS. NED's experience with flood warning is detailed in the following section.



TYPICAL ALERT CONFIGURATION

FIGURE 2

c. New England Division Experience with Flood Warning

New England Division has implemented one ALERT flood warning system and is currently implementing another, although neither is in Connecticut. The first is for the Pawtuxet River in Warwick, Rhode Island and the second for the Connecticut and Westfield Rivers in West Springfield and Springfield, Massachusetts. Both flood warning systems were implemented in conjunction with structural solutions to flooding. Considerable advice and assistance from the NWS was provided in the Corps formulation of the systems.

The Warwick flood warning system was implemented in conjunction with the acquisition and demolishing of 59 residential structures, the acquisition of 19 privately owned vacant lots, and the raising of utilities from the basements of 17 homes in the Pawtuxet River floodplain. Because the basements of the 17 homes would still be flooded, a flood warning system was included as part of the plan to give residents time to move damageable property and to evacuate their homes. The flood warning system hardware consists of four remote-reporting precipitation gages, three remote-reporting stream stage gages and a base station microcomputer located at Warwick's Police Station. In support of this system, the NWS agreed to prepare a flood forecasting model for the basin, but has not. NWS has stated that it is very difficult to prepare timely forecasts for the Pawtuxet River basin because it is so highly regulated. Local authorities have not been provided with any mechanism for flood forecasting. An emergency response plan has not been developed either. Despite the fact that the system was not complete in these respects, the Corps turned over the system to the local authorities. Since then, many of the remote-reporting gages have been frequently vandalized. Because the system never functioned properly, this flood warning system could be considered a failure. There is no current activity to correct the system's deficiencies.

The West Springfield/Springfield flood warning system is being implemented in conjunction with the raising of 3400 feet of the Corps' West Springfield Project floodwall. The purpose of the flood warning system is two-fold: to save lives by timely evacuation of the floodplain and to allow some damage reduction by the moving of items out of the path of the floodwaters. Flood forecasts for two rivers, the Connecticut and Westfield Rivers, were originally to be part of this project. For the Connecticut River, no new gages were to be implemented, however, West Springfield's lead time of predicted flood stage at the existing forecast point in Springfield was to be increased. For the Westfield River, four precipitation and two river stage gages have been located in the basin to remotely-report to a computer at the West Springfield Fire Station base station. The purpose is to allow for a timely stage forecast for the Westfield River at a USGS gage in nearby Westfield. The flood warning system is not, however, being implemented with communcation links to the RFC computer or with a resident computer forecast model as planned, possibly due to the fact that Corps involvement is apparently ending with hardware installation. The system has not yet, however, been turned over to local authorities, and the system has remained untested to date.

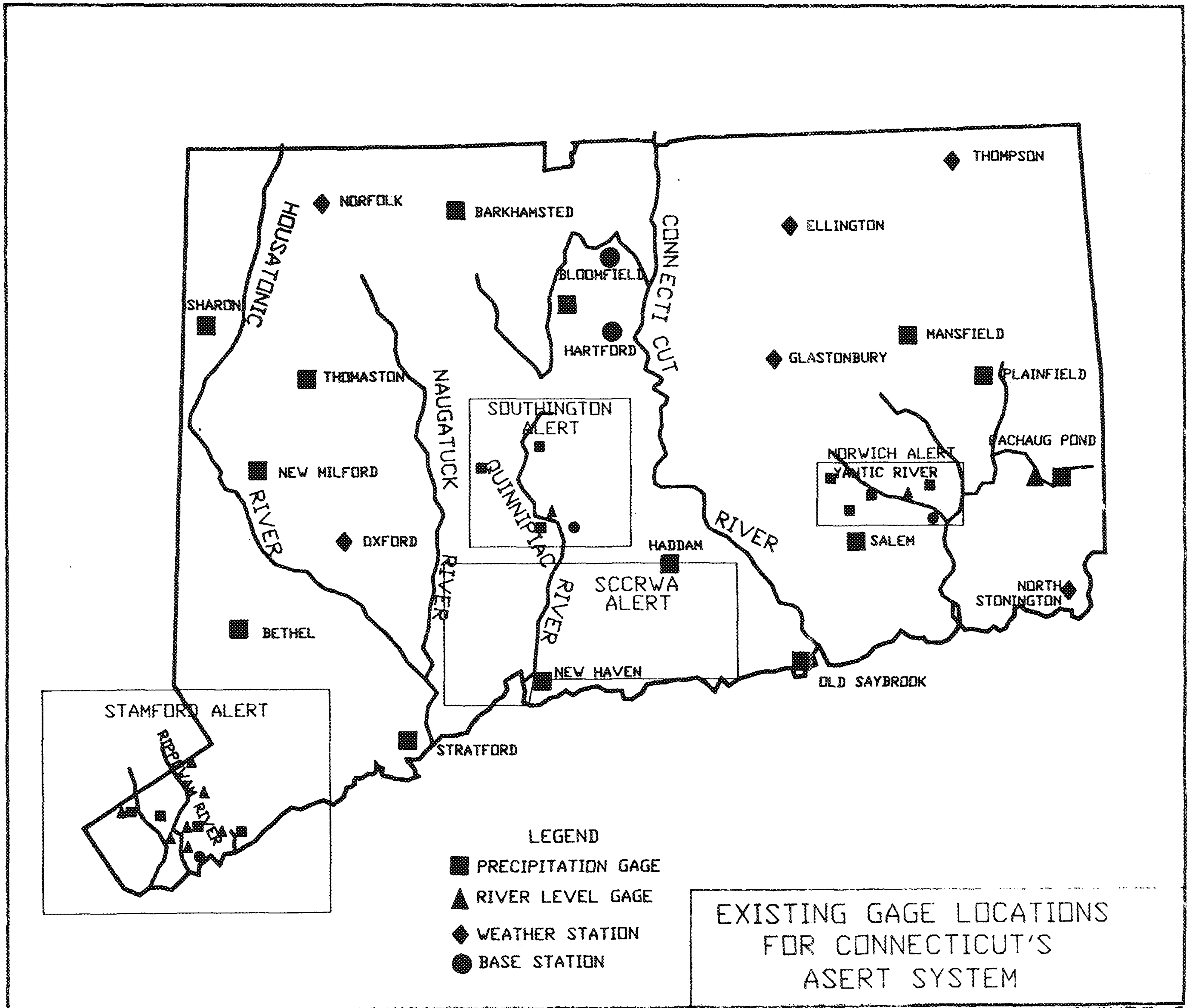
d. Connecticut's Automated Statewide Evaluation in Real Time (ASERT) System

In 1985 and 1986, Connecticut's Committee on Automated Flood Warning implemented a statewide network of remote-reporting sensors for two primary purposes: to facilitate an early state and municipal response to flood events; and, to collect data for the state's meteorological and climatological data base. The system, known as the Automated Statewide Evaluation in Real Time (ASERT) system, enables flood event response through the state and NWS monitoring and detection of weather events in the state capable of producing floods, and the subsequent issuance of warnings of potential flood events to municipalities with and without local flood warning systems. Municipalities with local flood warning systems may receive site-specific warnings, while those without local systems may receive general warnings. The ASERT system presently consists of 22 remote-reporting precipitation gages, 6 remote-reporting weather stations, 6 repeater sites, and two base stations with computers that receive and decode the signals (see Figure 3, Existing Gage Locations for Connecticut's ASERT System). Base stations are located at the DEP's Water Resource Unit office in Hartford, Connecticut, and at the RFC facility in Bloomfield, Connecticut. The ASERT system also serves to link local ALERT flood warning systems to both the DEP and NWS. The DEP and RFC base stations receive ASERT and ALERT system gage data via line-of-site radio waves, with radio wave repeaters sometimes required to re-transmit the signals around mountains and other obstacles.

The local ALERT flood warning systems linked to the ASERT system, also have base station computers. These computers, typically located in the vicinity of the local damage centers, generally receive only data from the gages in the contributing drainage basin and its immediate vicinity. Communication between NWS, DEP, and local flood warning system users may occur by telephone. Backup communications between the local system users and the RFC may be provided by Connecticut's existing National Warning System (NAWAS).

The initial layout of the ASERT system included two local ALERT flood warning systems in order to test the applicability of the hardware for the preparation of numeric river stage forecasts at the two forecast locations. ALERT systems were implemented for the Yantic River in Norwich, Connecticut and for the Quinnipiac River in Southington, Connecticut. Norwich's ALERT system consists of 4 precipitation gages and 1 river stage gage which remotely transmit data to the city's two ALERT base stations. Southington's ALERT system consists of 3 remote-reporting precipitation gages, a river stage gage which can be queried over the telephone lines, and a base station located in their City hall. Other systems linked to the ASERT system since that time include the pre-existing ALERT systems for Hartford, Connecticut and for Stamford, Connecticut, and the water supply monitoring system of the South Central Connecticut Regional Water Authority.

The state has estimated that installation, operation and maintenance of the completed ASERT system, including nearly twenty-five ALERT systems, will cost approximately 2.7 million dollars over a nine year period. This estimate does not include any preparedness planning costs, nor personnel training costs. The state DEP funds 66 percent of the capital cost of new



THOMPSON
NORFOLK
BARKHAMSTED
ELLINGTON
HOUSATONIC
CONN ECTI CUT
BLOOMFIELD
SHARON
HARTFORD
MANSFIELD
GLASTONBURY
THOMASTON
NAUGATUCK
PLAINFIELD
SOUTHINGTON ALERT
PACHAUG POND
NORWICH ALERT
YANTIC RIVER
NEW MILFORD
QUINNIPIAC
RIVER
OXFORD
SALEM
HADDAM
RIVER
SCCRWA ALERT
NORTH STONINGTON
BETHEL
NEW HAVEN
OLD SAYBROOK
STAMFORD ALERT
RIPPOWAM RIVER
STRATFORD
LEGEND
PRECIPITATION GAGE
RIVER LEVEL GAGE
WEATHER STATION
BASE STATION
EXISTING GAGE LOCATIONS FOR CONNECTICUT'S ASERT SYSTEM

FIGURE 3

remote-reporting gages for local ALERT systems in Connecticut that link to the ASERT system, and performs and funds all of the remote hardware maintenance.

Users of the data from the ASERT system also include the DEP Forestry Unit, the DEP Natural Resources Center, dam safety personnel at the DEP Water Resources Unit, and NWS weather forecasters.

e. Discussion of the Role of NWS in Flood Forecasting

The River Forecast Center (RFC) of the NWS issues site-specific river stage and crest time forecasts for locations along rivers with long lead times (usually 12 hours or more). The usual forecast procedure of the RFC during flood scenarios is to formulate and issue river stage forecasts at approximately 11 A.M. and 11 P.M. NWS's effort in providing forecasts for most rivers and streams with lead times of less than 12 hours is, however, limited. For areas with such rivers and streams, the Weather Service Offices of the NWS issue general (i.e. not site-specific) forecasts in the form of county-wide Flash Flood Watches and Warnings.

In many cases, the emergency response officials of areas with rivers and streams with short lead times prefer or require site-specific forecasts. To meet their needs, the RFC has instituted a program to assist communities in implementing their own "self-help" local flood warning systems. In this program, the RFC provides technical assistance in system development, and provides simple manual methods that can be used by local users to roughly determine peak river stage at the local forecast point when the RFC cannot prepare a forecast. The RFC cannot guarantee that they will be able to prepare a forecast for these points due to constraints imposed by limited funding and personnel. It is likely that their ability to assist communities in implementing local flood warning systems will decrease as more systems are implemented.

The NWS support of local flood warning systems was questioned by the Corps in conjunction with its work regarding Milford. Forecast procedures for the existing ALERT systems in Connecticut were found to be unclear, and not formally established. Of the two original ALERT systems linked to the ASERT statewide system, only the 90 square mile Yantic River basin in Norwich has a forecast routine. The forecast routine is executed by the River Forecast Center. No routine has yet been developed for the 34 square mile Quinnipiac River basin in Southington. In addition, of New England Division's two local flood warning projects, only the 497 square mile Westfield River basin in Westfield, Massachusetts has a forecast routine, also executed by the RFC. No routine has been developed for the Pawtuxet River basin in Warwick, Rhode Island.

Although they could not guarantee the issuance of a timely river stage forecast for rivers and streams with short lead times, the NWS expressed no interest in automating the forecasts, citing both the numerous potential errors that could occur with the forecasts, and the lack of existing automated NWS river forecasting software. Nor was the NWS willing to support the existing automated river stage forecast software of private vendors. Instead, for such rivers, NWS was willing only to provide a simple manual method that would allow for local formulation of the general degree of flooding that could be expected during a rainfall event if NWS couldn't issue a timely forecast. The Corps believes that the state had a more specific level of river stage forecast in mind when it proposed a flood warning system for Milford.

Because it appeared that NWS would not support river stage forecast formulation by other entities for rivers with short lead times, and would not guarantee their preparation of a forecast, the Corps held meetings with RFC personnel, and then with personnel of the Eastern Region NWS Office to obtain a clear position on the NWS support of local flood warning systems.

In these meetings, the Corps determined that, although NWS has no national policy with regards to ALERT systems, the Eastern Region of the NWS does not fully support ALERT systems, considering them to be privately developed stand-alone flood warning systems. Instead, the Eastern Region supports development of IFLOWS (Integrated Flood Observing and Warning System) for flood warning purposes.

IFLOWS is a two-way interactive data and text communications network developed by the NWS that links several dispersed local area computers on a statewide basis. The local area computers receive data from remote sensors the same way as for ALERT systems; the hardware associated with such a system is the same as for ALERT systems. The main difference of IFLOWS from ALERT is that, with IFLOWS, the remotely-reported real time data from the various sensors is processed at the local computer and then transmitted via radio waves, microwave, telephone, or other means to the state's controlling computer; the controlling computer sends relevant data and messages back to the local computers. In effect, the state's controlling computer, usually located in the state's Emergency Operations Center, serves as a data and message distribution point for all of the local computers. IFLOWS uses NWS-developed software in the controlling computer and the local computers. At present, IFLOWS software can only handle information from precipitation-measuring sensors, although NWS believes that it will soon be modified to accommodate river stage information. Since IFLOWS does not handle river stage data, it cannot be used for river stage forecasting directly. Manual procedures are still required to predict river stages.

IFLOWS is fully supported by NWS, and all associated hardware and software is paid for by the NWS, however, no funds are available for the implementation of an IFLOWS flood warning system for at least the next three years. Typically, it takes either a major disaster to cause the NWS to fund an IFLOWS system, or congressional resolution for the development of a particular system. After an IFLOWS system is implemented, its operation and maintainance is turned over to the state.

Many of those in the field of flood warning believe that flood forecasts yield economic benefits only when the forecasts are specific (numeric) flood stage forecasts, because only then can effective damage-reducing actions be taken with the limited lead time. (A numeric forecast may not be as critical for saving lives or reducing injuries). Because manual procedures must be used with the IFLOWS system, IFLOWS does not appear to address the problem of insufficient NWS resources to forecast river stages for short lead time streams.

Connecticut's ASERT system, at the time of its initial development, had the full support and encouragement of NWS. Connecticut's system is a hybrid flood warning system, with some data sharing features similar to that of IFLOWS, and some of the independent features of a stand-alone ALERT system. It is apparent that Connecticut is satisfied with its statewide ASERT flood warning system and, therefore, is unlikely to change to an IFLOWS systems. The system proposed for Milford is hybrid in nature. NWS support of Milford's local system, therefore, cannot be counted upon when it is needed.

The state DEP provides some assistance to the local users in forecasting for rivers with short lead times in the event that NWS finds itself unable to prepare a timely forecast. Because the City of Milford will likely not have the willingness to prepare its own forecast, or the ability to calibrate an automated system, state assistance may prove invaluable if NWS assistance is lacking. Personnel at the state DEP have taken a personal interest in the forecasting of river stages for the ALERT systems in the state. The state has been unofficially testing and preparing its own (un-issued) river stage forecasts for both the Norwich and Southington systems. In response to Corps concerns regarding the lack of a NWS guaranteed commitment to Milford's river stage forecasting needs, the state will be purchasing, testing, and calibrating a private vendor's fully-automated river stage forecast model for the Wepawaug River.

3. FLOOD HAZARD ANALYSIS

a. Flood History

Flooding has only become a problem along the Wepawaug River basin in the past 20 years. Minor flooding occurred on 29 January 1979 (peak flow of 1600 cfs at the former USGS Walnut Street gage in Milford), 10 April 1980 (1500 cfs at the gage), and April of 1983 (undetermined flow at the gage). Flooding apparently begins when flows are between 1400 and 1500 cfs. The flood of record occurred on 6 June 1982 when an estimated flow of 5000 cfs occurred at the gage (approximately a 100-year flood). This discharge was more than three times the previously estimated historical flow. The 1982 flood followed a prolonged rainfall averaging approximately 11.5 inches over the basin, and caused major economic damage. No lives have yet been lost due to Wepawaug River flooding.

b. Hydrologic and Hydraulic Relationships

There are no continuous long term discharge records available in the Wepawaug River basin. The U.S. Geological Survey (USGS) had maintained a peak discharge gage on the Wepawaug River from 1962 to 1982, just downstream of the Walnut Street bridge in Milford. Drainage area at the gage site is 18.4 square miles. The greatest flow occurring at the gage was about 5000 cfs, experienced in June 1982.

Hydrology for the Wepawaug River was determined by the Corps and others by analyzing the annual peak flows at the Walnut Street gage. A comparison of the peak flows listed in Milford's Flood Insurance Study (FIS) (Ref. 2) to those given in the Corps Detailed Project Report for the Wepawaug River (Ref. 10) indicated a significant difference in estimated peak flows for the various recurrence intervals. The Corps-estimated peak flows were found to be significantly higher than those listed in the FIS, particularly at the longer recurrence intervals. Further investigation into the hydrologic methods used to estimate the flows indicated that the hydrologic analysis used for the FIS was also based on the records of the Walnut Street gage, however, the June 1982 peak flow was omitted from the analyzed record because it was felt by the hydrologists to be an outlier. The Corps had, however, included the June 1982 peak flow in its analysis, since it had determined, by comparison to regional hydrologic relationships developed, that the flow was not unusually high for the short period of record analyzed, and, therefore, should be included in the analysis. Corps-estimated peak flows were therefore adopted in this report for purposes of determining economic flood damages at various recurrence intervals. Table 1 lists the Corps-calculated peak flows of the Wepawaug River at various recurrence intervals.

TABLE 1 - PEAK FLOWS OF THE WEPAWAUG RIVER
AT THE WALNUT STREET GAGE IN MILFORD

Recurrence Interval (years)	Peak Flow (cfs)
10	1700
50	3700
100	5000
500	9400

Weapawaug River flooding can be caused by excessive rainfall, a combination of rainfall and snowmelt, or dam failure from one of the two small dams in the basin.

The 100-year Wepawaug River flood profile and the floodplain delineation had been prepared by the Corps as part of its Detailed Project Report. Because the experienced June 1982 flood and the 100-year flood are considered to be equivalent, they are referred to interchangeably. Plates 2 and 3 show the plan and profile for the Wepawaug River. Since neither channelization or any other flood protection alternatives were implemented, the profiles showing their effect should be ignored.

c. Flood Depths and Velocities

After the disasterous Wepawaug River flood of June 1982 (100-year flood), building-by-building damage surveys were conducted. Flood depths reported at the floodplain businesses were generally on the order of 3 to 4 feet, with maximimum flood depth approaching 7 feet. Average overbank velocities ranged from one to four feet per second. Depths and velocities are generally considered hazardous when greater than 18 inches or 3 feet per second, respectively.

d. Evaluation of Existing Flood Detection and Warning Capabilities

Currently, there is no reliable means of detecting and predicting an impending flood of the Wepawaug River. Milford receives only NWS-prepared county-wide warnings of the possibility of flooding of small rivers through the NWS Flood Watch and Warning Program. In general, officials are tipped-off to Wepawaug River flooding only after overbank flooding has begun, or is about to occur.

Milford has no formalized arrangement for notifying occupants of the Wepawaug River floodplain to provide warning time. The experience from the June 1982 flood of record indicates that some warning time is likely before a major flood, however none is guaranteed. The warning provided by city officials to floodplain residents during this flood was apparently sufficient to allow for evacuation of the floodplain. Because of the lack of formulation of a predicted peak flood stage, or the time to the expected flood peak, little time was available for purposes other than evacuation. It should be noted that the peak of the 1982 flood occurred during the middle of the night when businesses in the floodplain were closed, and therefore unoccupied. The warning given to floodplain occupants was given by the sounding of sirens, followed by the knocking on doors by police. Although the message was received by occupants, many did not evacuate; perhaps this was because the residents had never seen a major flood of the Wepawaug River, and did not believe that they would be personally affected.

4. FLOOD DAMAGE EVALUATION

a. Identification of Flood Hazard Area

The Corps Detailed Project Report had broken Milford's 1.5 mile damage center into 4 damage reaches, as indicated on the flood profiles shown on Plates 2 and 3. Because the flood warning system addressed in this report is planned to benefit the same damage area, the 4 reaches are similarly grouped and described. The floodplain development described in each reach is that in the 100-year floodplain. There are many residences, private businesses, public buildings, and an industrial facility in the floodplain. There are no sites in the floodplain that would require special consideration such as hospitals, schools, chemical storage sites, etc. In addition, an examination of topography shown on the USGS topographic maps indicate that there is little potential for residents becoming trapped or isolated from evacuation routes.

Reach 1 of the Wepawaug River damage area begins just downstream from the New Haven Avenue (Route 162) dam and bridge, and extends upstream to the City Hall Dam. The New Haven Avenue dam prevents tidal influence on the Wepawaug River floodplain. Development in the floodplain in this reach includes 31 businesses and 4 public buildings: City Hall, St. Peters Church, the court house, and the library.

Reach 2 extends from the City Hall Dam upstream to Maple Street. No damages are experienced in this reach.

Reach 3 extends from Maple Street upstream to U.S. Route 1 (Boston Post Road). A predominant feature in this reach is the scenic "duck pond" and surrounding park area located upstream from Maple Street. Development in the floodplain in this reach includes 12 businesses, 4 North Street homes, and 4 West Street homes.

Reach 4 begins at U.S. Route 1 (Boston Post Road) and extends to the upstream study limit located 1800 feet upstream from Interstate Highway I-95. The old USGS Walnut Street gage site and Interstate Highway I-95 are located in this reach. Development in the floodplain in this reach includes 9 businesses, 24 homes on North Street, 11 homes on Dale Drive, and a large industrial plant upstream from I-95. The vast majority of flood losses in the Wepawaug River floodplain occur at the industrial plant.

b. Type of Damages

A field survey of flood damages in the Wepawaug River floodplain was made by the Army Corps of Engineers following the disasterous June 1982 flood (100-year flood). A building-by-building inventory of experienced flood damages was conducted for all commercial and public structures in the floodplain. Losses that could be expected at various flood stages, as related to the June 1982 flood stage, were also assessed. Damages were separated into several categories including stock and contents, equipment and machinery, etc. Damages for private residences were not broken into category types, however. An analysis of the field-surveyed data indicates that a significant percentage of the flood damages are stock and contents damages. Stock and contents, being moveable on short notice, are the type of losses that can be reduced through flood warning. Stock and contents losses account for approximately 2/3 of the total average annual damages in the Wepawaug River floodplain.

c. Structural Solutions to Flooding

The Army Corps of Engineers DPR had recommended the construction of a dike and channel widening to protect one industrial firm and several homes in the upper study reach. No cost-effective solutions were found for the lower (downtown) area. Neither dike construction nor channel widening occurred. A study conducted subsequent to the DPR by a private engineering firm also concluded that the Corps-proposed dike and channel widening was the only feasible structural solution to flooding.

A berm was partly constructed by private interests in order to protect a large industrial facility, located in the upper study reach, that receives a large percentage of the total damages in the Milford study area. The City, however, issued a Cease and Desist order to the owner of the facility before it was completed. The order was issued because of complaints by neighbors that feared the hydraulic impact of the berm on their properties.

d. Damage Reduction Associated with Provision of Warning Time

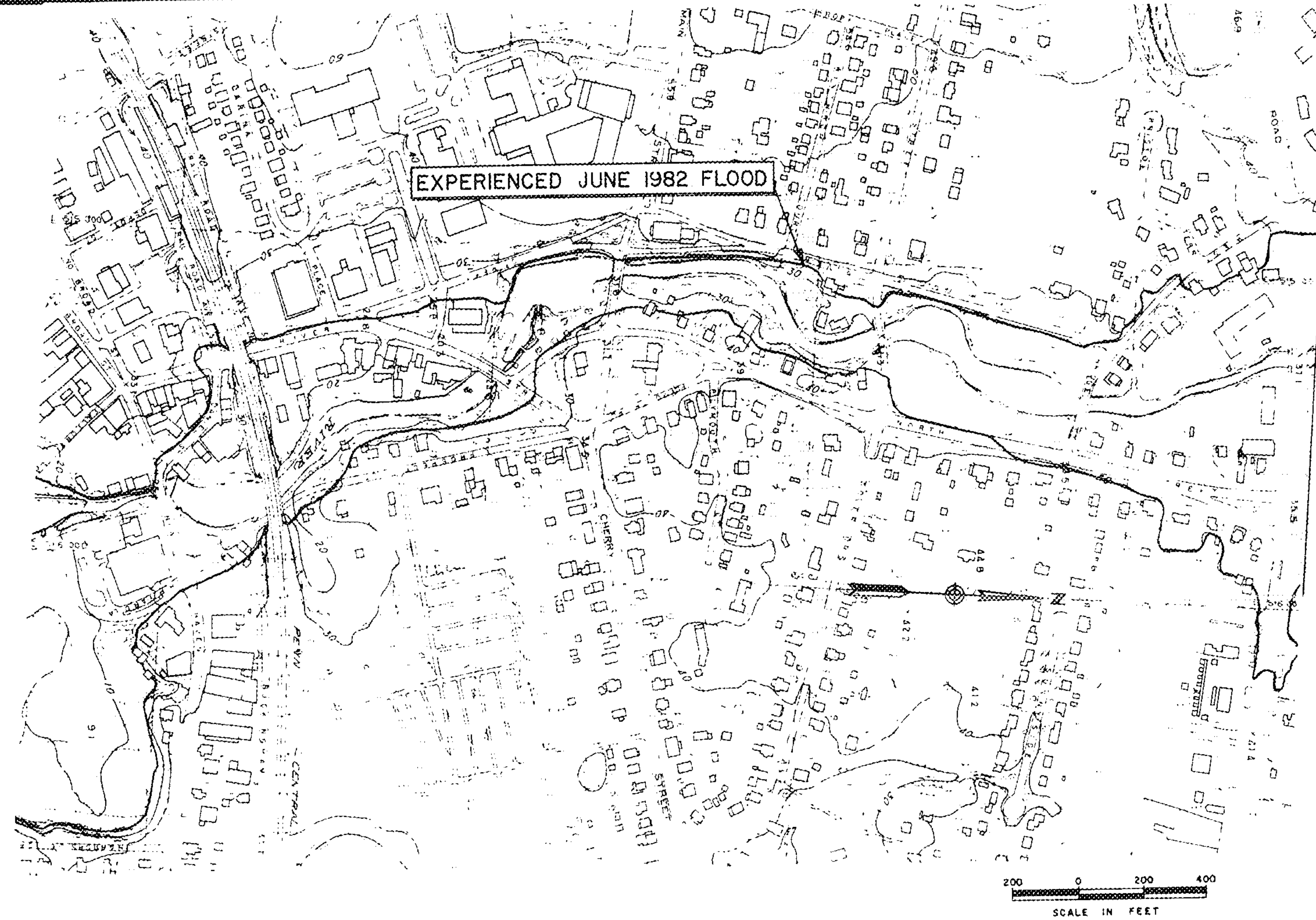
An analysis of potential damage reduction by providing warning time to floodplain occupants, such as could be provided by a flood warning and response system, was performed. The warning time could be utilized to allow floodplain occupants to move stock and contents and automobiles out of the path of the floodwaters prior to floodplain evacuation. There are no commonly accepted or established methods for evaluating the benefits of warning time, and therefore several assumptions were made. The preliminary analysis indicates that there are significant benefits associated with providing warning time to the floodplain occupants.

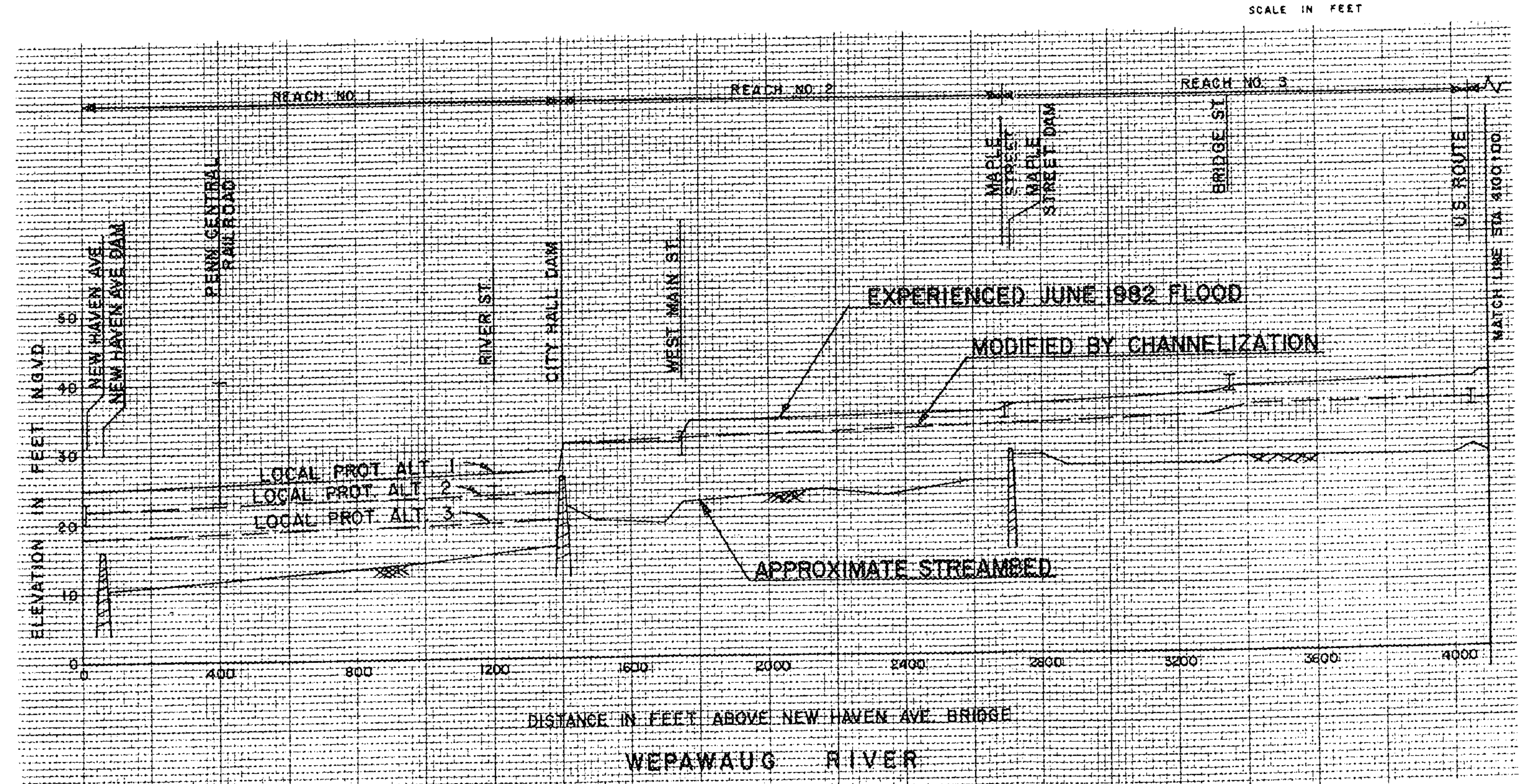
The benefits attributed to providing increased flood warning time are assumed to be entirely from reduced damages to stock and contents in buildings. Although automobiles may also be moved out of the path of the forecasted floodwaters, the economic benefit associated with their removal from the floodplain was not calculated.

Existing forecast warning time without a flood warning system was assumed to be timely enough only for floodplain evacuation. A 2.5 hour increase in warning time was an assumed value felt to be realistic (by the State and the National Weather Service) for a local flood warning system provided that individual forecasting attention is given to the basin by some party, or if an automated forecasting routine is successfully incorporated into the base station computer.

Corps field-surveyed damage data was used to evaluate the potential reduction in damages with 2.5 hours of additional warning time. The building-by-building analysis of the type and dollar value of flood damages for each commercial, industrial, and public building in Milford's

U. S. ARMY





REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

DES. BY | DR. BY | CK. BY

SUBMITTED:

CHIEF, CIVIL ENGR. SECTION

APPROVAL RECOMMENDED:

CHIEF, DESIGN BRANCH

REVIEWED:

PROJECT MANAGER

APPROVAL RECOMMENDED:

CHIEF, BRANCH

WEPAWAUG RIVER BASIN
WEPAWAUG RIVER, CT.

PLAN AND PROFILE # 1

MILFORD, CT.

HYDRO. ENG. SECT.

APPROVED | DATE

CHIEF, ENGINEERING DIVISION

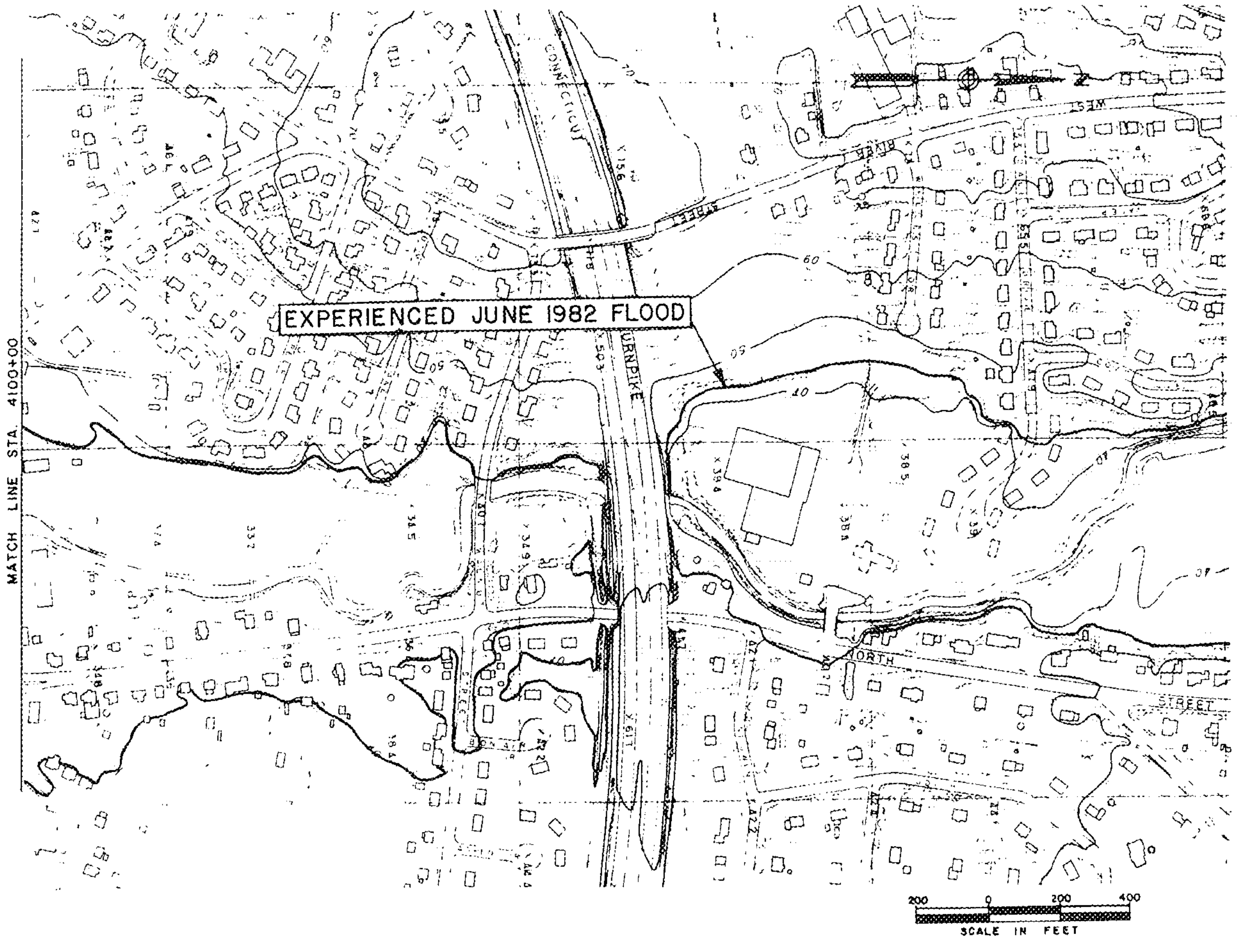
SCALE | SPEC. NO.

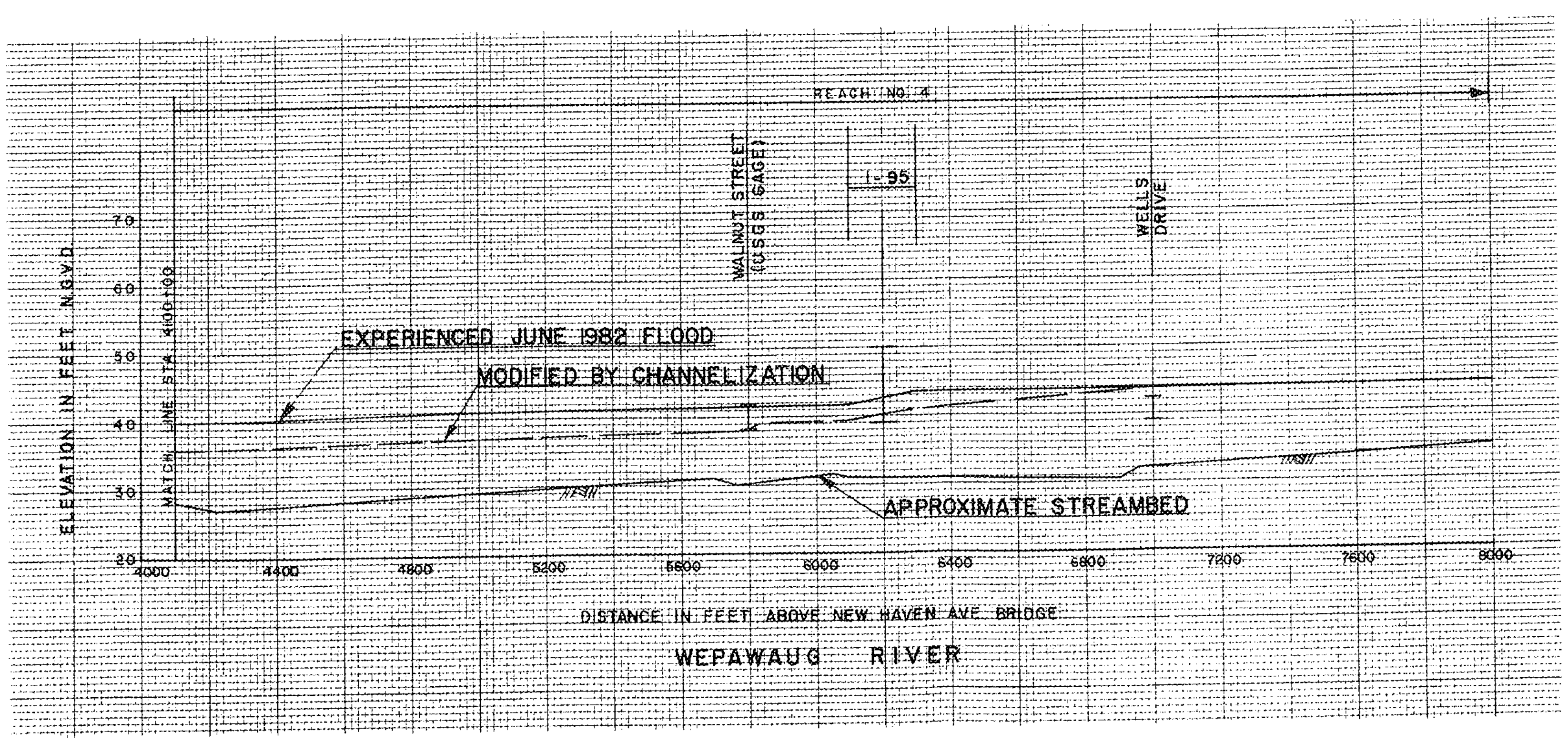
DRAWING NUMBER

SHEET

PLATE 2

CORPS OF ENGINEERS | A | B | C | D | E | F | G | H | U. S. ARMY





SAFETY PAYS

REVISION	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

WEPAWAUG RIVER BASIN
WEPAWAUG RIVER, CT.

PLAN AND PROFILE # 2
MILFORD, CT.

DES. BY | DR. BY | CK. BY
SUBMITTED:
CHIEF, CIVIL ENGR. SECTION
APPROVAL RECOMMENDED:
CHIEF, DESIGN BRANCH
REVIEWED:
PROJECT MANAGER HYDRO. ENG. SECT.
APPROVAL RECOMMENDED: APPROVED DATE
CHIEF, PROJECT BRANCH | CHIEF, ENGINEERING DIVISION
SCALE | SPEC. NO.
DRAWING NUMBER
SHEET

PLATE 3

100-year floodplain was utilized. The field visit estimated damages for various flood stages relative to the 100-year river flood stage (e.g. for 1 foot higher, 1 foot lower, etc.). The damage data was separated into various categories, including a stock and contents category. Damages were also annualized to yield average annual stock and contents damage for the Wepawaug River floodplain area.

A graph of percent reduction in total damages versus forecast lead time provided the general relationship used in this analysis to measure benefits. The graph was initially published in a report prepared for the National Weather Service (Ref. 4), but has since been used by many entities to show the general relationship of warning time to flood damage reduction. The curve is sometimes referred to as the "Day Curve", after Harold Day of NWS. Mr. Day conducted case studies of damage reduction versus warning time for residences in parts of New York and Pennsylvania. The time parameter used in the graph is "forecast lead time", which is not the same as "increase in warning time". Although it is not technically correct to use the graph to assess damage reduction using "increase in warning time", the substitution of the two terms for one another is felt to provide a result that could be used for the preliminary assessment of the value of providing warning time.

For the residences studied by Mr. Day, the maximum possible reduction in total damages approached 35 percent. The 35 percent value included moveable stock and contents only. The "Day Curve", being a graph of reduction of total damages versus time, was converted to a graph of percent reduction in stock and contents damages versus time. Using this converted curve, an increase in warning time of 2.5 hours was found to result in a 20 percent reduction in stock and contents damage. The Corps commercial, industrial, and public building-by-building stock and contents damage values for the various recurrence intervals were then multiplied by 20 percent to yield expected damage reduction values for those types of buildings. For residential buildings for which the Corps had only total damage information (no further breakdown) for each building, contents damage was assumed to be 20 percent of the total flood damage. Results of the calculations of stock and contents damage reduction in the study area with 2.5 hours of increased warning time for floods of various recurrence intervals are presented in Table 2.

Table 2 - Reduction in Stock and Contents Flood Damage in the Milford Study Area with 2.5 Hours of Increased Warning for Various Flood Recurrence Intervals (March 1988 dollars)

Recurrence interval (years)	Reduction in Stock and Contents Losses (thousands of dollars)
5	90
10	240
20	2640
50	9120
100	11,070
500	13,990

Using the data provided in Table 2, it is calculated that the average annual reduction in stock and contents losses with 2.5 hours of increased warning time would be $93,000.

The following important facts applying to the values cited in Table 2 should be noted:

1. Stock and contents losses account for 67 percent of the flood-related damages in the study area. This is an unusually high percentage of the damages. The values were, however, substantiated by the Corps field-surveyed data.

2. One industrial facility located in the upper study reach accounts for $66,000 of the $93,000 in average annual stock and contents loss reduction. Special attention should undoubtedly be provided to this facility in terms of message dissemination, etc.

3. Stock and contents losses were based on Corps field-surveyed observations following the June 1982 flood. If mitigating measures have been taken since then, the loss reduction values provided in Table 2 would be accordingly decreased. In addition, if the nature and value of the stock and contents has changed substantially since that survey, particularly at the industrial facility accounting for the majority of the stock and contents damage, the loss reduction values given may be substantially changed.

Mr. H. James Owen of Flood Loss Reduction Associates of Palo Alto, California visited the Wepawaug River floodplain of Milford in September of 1990 at the request of the Corps of Engineers. Mr. Owen is an expert on flood-specific emergency response planning. It was his belief that Milford could obtain significant reduction in flood damages through a flood warning system if a thorough flood-specific emergency response plan was developed and supported by local authorities. The availability of Corps field-surveyed damages on a building-by-building basis was felt to be a considerable asset that could lead to a highly detailed and useful flood damage-reducing plan.

5. STATE-PROPOSED FLOOD WARNING SYSTEM FOR THE WEPAWAUG RIVER

a. System Design

The general concept of flood warning by the state for the Wepawaug River in Milford was to implement a local ALERT flood warning system that would tie into Connecticut's statewide ASERT system. The purpose of the local warning system would be to provide floodplain occupants with time to move the considerable high value stock and contents and automobiles out of the expected path of the floodwaters, and to evacuate the floodplain. Evacuation of the Wepawaug River floodplain, although important, is not the main purpose of this system. This is due to the ease of evacuation of the floodplain due to its narrow width, the short time period of high water, and the lack of facilities that would require relatively long times to evacuate such as hospitals or nursing homes in the floodplain.

As proposed, the ALERT system's remote-reporting rainfall and river stage gages will be monitored on computers at three separate locations. One computer will be located at a round-the-clock fire station in the City of Milford. Other monitoring computers will be the existing ASERT-monitoring computers located at the state DEP Water Resources Unit and at the NWS River Forecast Center. The system will be alarmed so that when any rain or river stage exceeds a pre-determined threshold value or rate, an alarm will automatically sound at the three monitoring computers. NWS believes that a qualitative forecast could be provided by the proposed warning system along with two to three hours of warning time. However, to provide this length of lead time, individualized attention will have to be provided to the system by either the NWS, the state, or the local users. Another way to obtain two to three hours of warning time, although not supported by NWS, would be the incorporation of a totally automated forecasting model into the base station computer. In any case, to obtain a forecast at the forecast location with significant accuracy, several years worth of calibrating data will first have to be collected. Until then, the system, at its best, will have the potential to yield only a qualitative forecast.

The state DEP has coordinated the various tasks needed to implement the local flood warning system. These tasks have included the preparation of an application to the Federal Emergency Management Agency for partial system funding, the determination of the system hardware quantities and specifications, the proposing of a physical layout of the gages, the testing of radio wave paths to determine if a radio wave repeater would be required, and the negotiating of land rights at the gage sites. The system hardware specified is the same as that of other ASERT system hardware. One item specified for purchase for Milford's system not yet included for other local systems was an automated river stage forecasting software package, and not merely a software program that only collects and displays data. Purchase of this package was due, in part, to concerns of the Corps of Engineers regarding the timely preparation of a forecast, since the small basin size and resulting quick responsiveness of the basin will require a forecast to be prepared quickly. The state, possibly with RFC assistance, intends to test and calibrate the automated model.

The City's base station computer will be located at the Fire Station (see Plate 4, Milford ALERT System Layout). There will be one combination river stage/precipitation gage located near the industrial firm suffering a large percentage of Milford's flood damages. Other remote-reporting precipitation gages will be located at a small airport in Ansonia and at a traveller's rest stop on Route 15 in the Town of Orange. These sites are believed to be relatively vandal-proof sites. Other gages that may be used for purposes of flood warning for the local system are the existing South Central Connecticut Regional Water Authority (SCCRWA) combination precipitation/lake level gages at Wepawaug Reservoir (drainage area = 7.7 square miles) in the Town of Orange, and at nearby Lake Dawson in the Town of Woodbridge, although it is not within the basin. SCCRWA's Burwell Hill Repeater will be used by the DEP and RFC to receive the remote gage data.

The cost of the flood warning system hardware was estimated by Sierra Misco flood warning system manufacturers for the state DEP. Costs are estimated as follows:

Item	Unit Price	Quantity	Installation	Total Cost
Comb. precip./river gage	$4665	1	$ 750	$5415
river gage cable	$2.50/ft	30 ft	$ 0	$ 75
precip. gage	$3000	2	$1000	$7000
receiver/decoder	$2600	1	$ 0	$2600
antenna & cable	$ 205	1	$ 0	$ 205
data command software	$5000	1	$ 0	$5000
river forecast model	$1500	1	$ 0	$1500
printer	$ 500	1	$ 0	$ 500
computer - 286 class	$8000	1	$ 0	$8000
Total cost				$30,295
10 % contingency				3,030
Grand total				$33,330

As can be seen from the table, the total estimated cost of the local flood warning system is $33,330, including contingencies. Annualized cost of the system is approximately $7400 based on this initial cost, a 10 year life of the project, a discount factor of 10 percent, and an assumed annual maintenance cost equal to $2000 per year (the state's estimate). Since the average annual benefit (i.e. reduction in stock and contents losses) is estimated at $93,000 with 2.5 hours of increased warning time, a benefit/cost (B/C) ratio of 12.5 is calculated. This B/C ratio does <u>not</u> include the costs of computer model setup or calibration, nor the substantial local costs of flood-specific emergency response planning.

b. Description of Typical Flood Warning/Response Scenarios

A description of how the proposed local flood warning and response system would be expected to function during a flood threat is provided. The description is broken into the four components of a flood warning and response system discussed previously.

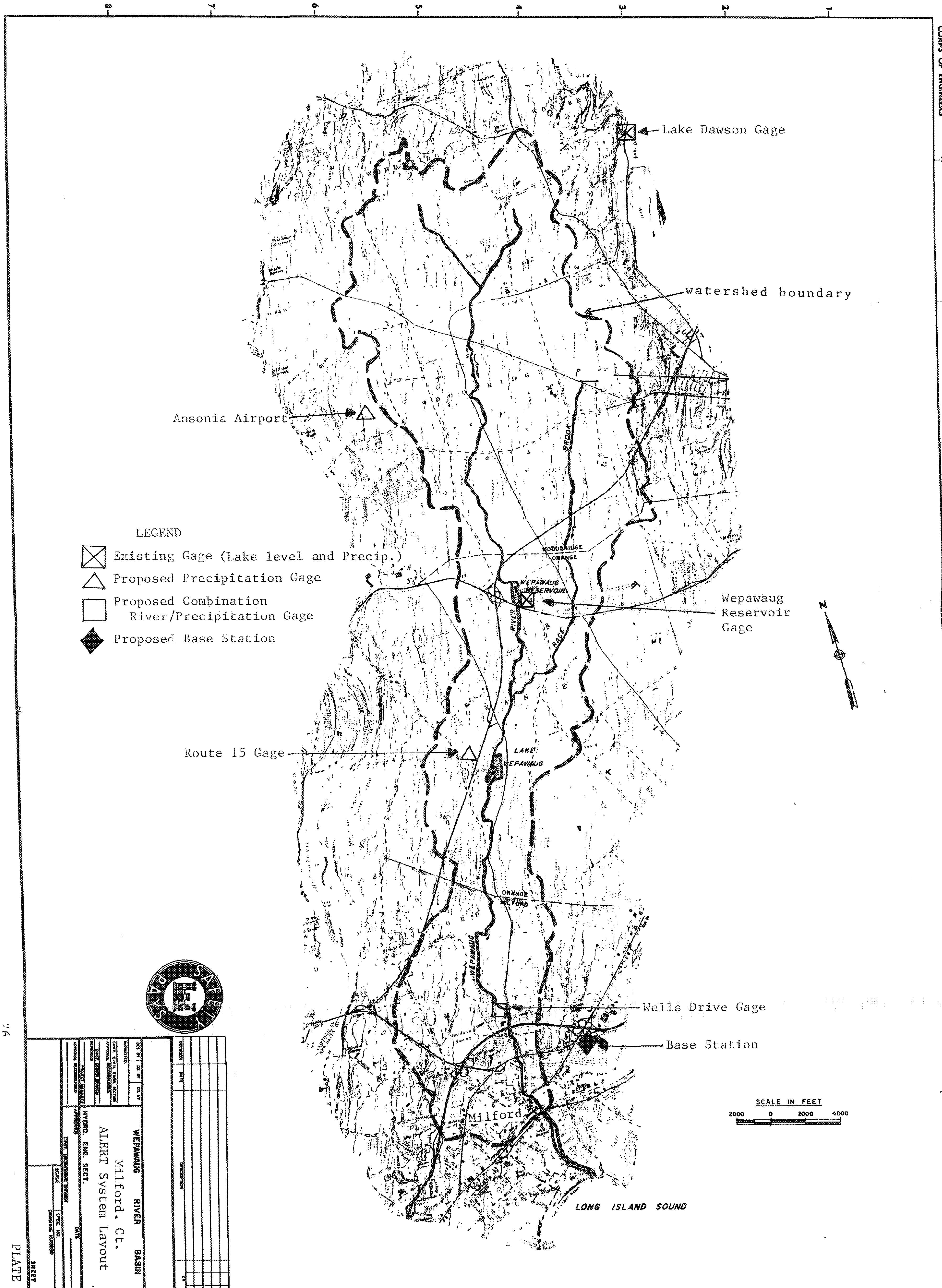

Lake Dawson Gage
watershed boundary
Ansonia Airport
LEGEND
Existing Gage (Lake level and Precip.)
Proposed Precipitation Gage
Proposed Combination River/Precipitation Gage
Proposed Base Station
WOODBRIDGE
ORANGE
WEPAWAUG RESERVOIR
Wepawaug Reservoir Gage
Route 15 Gage
LAKE WEPAWAUG
ORANGE
MILFORD
WEPAWAUG
Wells Drive Gage
Base Station
Milford
LONG ISLAND SOUND
SCALE IN FEET
2000 0 2000 4000
CORPS OF ENGINEERS
U. S. ARMY
WEPAWAUG RIVER BASIN
Milford, Ct.
ALERT System Layout
HYDRO. ENG. SECT.

PLATE 4

The first component of a flood warning and response system is flood threat recognition. In the case of Milford, this will likely occur in one of two ways. The first way is by the sounding of an alarm at the round-the-clock staffed fire station's base station computer in Milford when a pre-set threshold is exceeded at one or more of the precipitation or river stage remote-reporting gages. The warning would likely come hours in advance of a potential flood. The sounding of the alarm will notify City officials of an event that they should begin monitoring. The appropriate emergency response officials can then be contacted for further guidance. Flood threat recognition occurring in this manner will likely be for an intense rainstorm occurring at night when state offices are closed. The second likely method of flood threat recognition will be through notification by the state or the NWS of a potential flood-producing weather event moving towards the Wepawaug River drainage basin. This type of warning may occur with a large general rainstorm. In this case, the event would likely first be detected by either the ASERT statewide system, or by the NWS through its information in adjacent states.

The second component of a flood warning and response system is forecast preparation and message formulation. In the case of forecast preparation for Milford, NWS has indicated that they cannot guarantee a timely forecast. During times of flood threat, NWS may or may not provide a forecast, depending on if they have the time or resources. Forecasts will thus have to be prepared by the city using either NWS-provided manual forecast methods, or using the privately-supplied software program that Milford's computer will be equipped with that, after calibration, will allow automated forecasts of expected river stages. In any case, several years worth of data will have to be gathered before the forecasts yield reliable numeric river stages. It is noted that the fully automated software package has been untested and its operation undemonstrated to date in the New England area. The State of Connecticut DEP may be available to assist the city in preparing a forecast for the Wepawaug River since it will have the automated forecasting model in its computer as well, and may have the time to adjust and calibrate it, and may have the NWS-provided manual forecast method for the Wepawaug River also. The responsibilities of forecast preparation must be institutionalized in Memorandums of Understanding between the city, the state, and the NWS. If this does not occur, a forecast may not be prepared during a flood emergency.

Message formulation is an important part of the second component of flood warning and response systems. The expected reaction of the intended target of the message(s) will have to be considered in its formulation. Explicit instructions on what to do will become part of this message; the wording of the message will affect the response. It is noted that beginning with this component of the flood warning and response process, emergency response actions and reactions are addressed. Preparation of emergency response plans is clearly a local responsibility since it is local authorities that will carry out any effort along these lines. To date, the City of Milford has not expressed an interest in Corps assistance with the emergency response process, nor has it displayed any initiative in preparing a flood-specific response plan on its own. To maximize the benefits of the proposed system, actions along these lines will have to be taken.

The third component of the flood warning and response system is warning message dissemination. The mechanism of transmitting the warning message to the public is detailed as part of this component. Because of the compactness of Milford's floodplain, warning message dissemination should be fairly straightforward. It may be through the sounding of sirens on police and fire vehicles to alert floodplain residents, perhaps followed by radio, television, or another means to disseminate explicit warning messages.

The fourth component of the flood warning and response system is the warning response. It is this component in which all of the benefits of flood warning arise. To date, Milford officials have not formally planned their response. The planned response to the warning may include the closing off of threatened bridges and low-lying roads, the moving of floodplain building stock and contents, the moving of automobiles, and the evacuation of the floodplain. The resources of the community likely to be available during times of flooding should be planned far in advance of any flood, and the shortfalls in resources available will have to be identified. Plans should be made for any outside assistance that will be required. The role of the city in assisting private businesses and homeowners, if at all, should be identified.

The availability of building-by-building flood damage data from the existing Corps Wepawaug River floodplain field surveys could enable preparation of flood audits for individual buildings, such as those that have been prepared by the Soil Conservation Service for floodplain residents in the two Connecticut communities with ALERT systems initially implemented in conjunction with the ASERT system. Flood audits are building-specific emergency response plans that enable floodplain occupants to translate the stage forecasted for the City's river stage gage (the forecast location) into a flood depth and corresponding response at their buildings. If sufficient warning time is provided, the occupants may raise their stock and contents above the expected flood stage at their buildings, and they may move automobiles prior to the evacuation of the floodplain.

Milford must make provisions to update the flood-specific response plan addressing their actions at least annually. Reasons for this are due to potential changes in employees and floodplain residents, changed hydraulic conditions, etc.

c. Anticipated Performance of System

The ultimate success of the system is difficult to predict. There are several factors that could lead to system success, and several that could lead to its failure. These factors are discussed below.

Positives

The flood warning system being implemented for the Wepawaug River has several factors that would appear to indicate potential long-range success for the system. These factors are largely due to the fact that the system will tie into the statewide ASERT system and, therefore, will receive state support. The benefits of state support include the insured long-range maintenance that the system will receive, the assistance with the computer hardware and software, and the knowledge gained by the state's general experience with flood warning.

The use of the system by non flood-related entities, such as the South Central Connecticut Regional Water Authority (for water supply purposes), should contribute to system success, by broadening the base of support for the system.

Another factor contributing to potential system success is that the floodplain residents have experienced a 100-year magnitude flood in the recent (June 1982) past. The disastrous nature of this flood could prompt the residents to effectively utilize the flood warning system. One of the system's potential major beneficiaries, the large industrial firm located in the upper study reach, has already expressed an interest in utilizing the warning for flood damage-reducing purposes.

The availability of Corps field-surveyed building-by-building flood damages could lead to formulation of a highly effective flood damage-reducing plan. The availability of this information could improve the ultimate effectiveness of the system.

Negatives

Factors contributing to the possible failure of the system include the apparent lack of interest by Milford's emergency preparedness officials or other local officials. Success of the system will depend on a strong interest in the system by local officials. Perhaps implementation of the system, along with successful initial system performance will spark their interest.

The infrequency of flooding of the Wepawaug River is a factor that could negatively impact the system's successful operation. It may be difficult to maintain interest in a system that is used infrequently. In addition, the lack of existing rainfall and river stage data for the Wepawaug River will mean that the capability of the system to yield specific river stage forecasts may be years off. The occurrence of a major flood or several minor floods may be needed before the system is properly calibrated.

An additional factor which could lead to system failure is the relatively short travel time of a flood wave because of the basin's small size and the resulting shortness of time to prepare and issue a flood forecast. Due to the nature of Milford's flood damages, it is felt that an accurate and specific flood stage forecast may be required in order to yield significant benefits. Forecasting arrangements for the Wepawaug River have not yet been institutionalized. It is not believed that the city understands the ramifications it may face if it must prepare the forecast on its own. For this reason, it is the belief of the Corps that success of the flood warning system during worst case scenarios (intense localized downpours) may be dependent upon the successful implementation of fully or nearly fully automated flood forecasting software.

6. NEW ENGLAND DIVISION CONCERNS REGARDING FLOOD WARNING SYSTEMS

New England Division has several concerns regarding flood warning beyond the usual concerns of insuring that local flood warning systems receive long-term maintenance, funding, and local support, and that a preparedness plan be prepared and kept updated. These concerns must be addressed before New England Division can fully support deployment of the systems. The reasonable cost of the hardware for flood warning systems cannot be disputed, but the effectiveness of such systems may be. New England Division's concerns are listed as follows:

1. The purpose of a particular flood warning and response system must first be defined and clearly understood by all involved parties before system development and implementation. Only <u>then</u> should a system be developed. A system for saving lives and reducing injuries may be different than one for reducing property damages, or one for merely gathering data.

2. An incorrect perception seems to exist concerning "automated" flood warning systems. This perception may have driven the implementation of some systems. "Automated" flood warning systems are not necessarily automated <u>forecasting</u> systems; only the <u>collection</u> of the remote data is typically automated. As implemented in the New England area, automated flood warning systems have largely yielded only unprocessed precipitation and existing river stage data, not a river stage forecast.

3. If the local systems are not fully automated, the preparer of the river stage forecasts must be clearly identified long before any flood. The lead time that would be available through this preparation procedure must also be identified. Those responsible for calibrating the forecast model must also be clearly identified. The Eastern Region of the NWS does <u>not</u> fully support ALERT flood warning systems, yet it is assumed by many parties that they do. Obviously a fairly high degree of technical knowledge and skill is required to either prepare an accurate forecast or calibrate a forecast routine. NWS will not guarantee that they can provide a timely river stage forecast, nor will they calibrate automated forecast computer models. For Milford, it is still not known who or how the State-promised river stage forecast will be prepared. NWS has stated that it will provide the city with a method to allow for the manual preparation of forecasts. In the past, NWS has promised similar forecasting methods for other ALERT systems in New England, but has not always delivered.

4. The specificity of forecasts that these systems are <u>capable</u> of yielding may also be incorrectly perceived. In many cases, ALERT systems may yield only qualitative forecasts, particularly if little calibrating data is available for the river. The NWS claims that, even with a reasonable amount of time and resources, the best that their professional forecasters can get Milford's flood warning system to yield is a categorical forecast with a relatively wide confidence interval (i.e. lack of certainty). It is not known if private vendor hydrologists can do any better than this. In New England, it has not

been demonstrated that specific river stage forecasts can consistently result from these systems.

5. There does not appear to be much science that goes into the design of ALERT systems. In the New England area, the number of gages deployed is apparently determined by employing rules-of-thumb. The sizes of potential storm cells do not appear to affect the number of gages specified. The nearness of other remote-reporting gages does not appear to affect the system design. Perhaps the relative sophistication of the hardware technology implies a science that does not exist.

6. Perhaps the Corps should not implement systems that, at least in the New England area, may depend to a large extent on the private sector for successful performance, particularly with respect to forecasting software. The private sector may be more concerned with sales of their hardware and software than insuring that a useful cost-effective end product result.

7. Perhaps the Corps should not implement systems requiring such a major and essential role on the part of local authorities in the preparation of flood-specific emergency response plans. Few benefits are likely to result if this aspect is not properly addressed.

8. The benefits attributed to flood warning and response systems in the planning process are usually based upon the issuance of timely and specific river stage forecasts which are assumed to result from a flood warning system's implementation. In general, the assumed benefits of flood warning and response systems appear to be based more on <u>theoretical</u> performance than <u>demonstrated</u> performance.

9. NWS is undergoing a major modernization and restructuring effort during the 1990's, with the implementation of new highly automated weather observing systems and computers to process and analyze the data. The impact of this effort on the need for local flood warning and response systems is unknown, but should be determined. Perhaps the major automated technological and analytical advances being implemented in this modernization can be applied to flood warning efforts as well.

7. POTENTIAL ROLE OF FLOOD PLAIN MANAGEMENT SERVICES IN FLOOD WARNING AND RESPONSE

a. Technical Evaluation of the Flood Hazard

The technical evaluation of a river's flood hazard has been and should continue to be one role of the Corps FPMS program. The Corps can continue to utilize its extensive knowledge of floodplains to assist communities in defining the boundaries of the flood hazard areas, the expected depths and flow velocities of the floodwaters, the elevations of the flood (versus various frequency flows), the flood wave travel time to determine warning time, etc. Maps of the flood boundaries at various river stages may be prepared for use by the local emergency officials in conjunction with numeric or categorical river stage flood warnings.

As part of the Corps work on the Wepawaug River flood warning system, the 10-, 50-, 100-, and 500-year floodplain boundaries were identified. By superimposing the Corps-prepared floodplain boundary maps upon the city assessor's maps, the street addresses of those in the various floodplains were identified. Both the maps showing floodplain boundaries and the lists of those affected by the various frequency floodplains were provided to the city by the Corps in an earlier report (Ref. 7). City officials may use this information in the preparation of flood-specific emergency response plans.

b. Assistance with Preparation of Warning and Response Arrangements

The Corps can assist communities in evaluating the sufficiency of the existing flood warning and response arrangements for the purpose of life loss prevention and/or property damage loss reduction. The Corps can assist communities in the preparation of flood-specific emergency response plans based on experience obtained with the hurricane evacuation program. With local support, the Corps could serve as coordinator in developing warning and response procedures.

c. Design of Flood Warning Systems

The Corps could become involved in the design of local flood warning systems. System design is now done largely by private vendors that sell the flood warning hardware or by the NWS using general rules-of-thumb. The concerns raised in Section 6 (above), however, should be thoroughly addressed before support and design of a particular flood warning system is given by the Corps.

d. Evaluation of the Effectiveness of Flood Warning and Response Systems

The FPMS program could evaluate the effectiveness of existing flood warning and response systems. It is believed that, by and large, these systems are justified based on a theoretical, but undemonstrated, basis.

The Corps could develop a method of evaluating the economic and other benefits of a flood warning and response system that would be tied to specific design features, the planned actions of emergency response officials, the presence or absence of flood audits for buildings in the floodplain, the warning time allowed, the specificity of the forecast, the demonstrated accuracy of the forecast, etc. It is evident that many variables would have to be incorporated into an evaluation of this type.

8. CONCLUSIONS

A local flood warning and response system may reduce injuries and the loss of lives due to flooding by allowing for timely evacuation of the floodplain. A local flood warning and response system may also allow a significant reduction in property damages by providing additional warning time for floodplain residents to take mitigating actions. Because a flood warning system can be considered a low cost alternative to a structural solution to flooding, and because its environmental impact is minimal, implementation of such systems is being considered more often in the New England area.

In New England, there are now six local flood warning systems, two of which are Corps systems implemented in conjunction with structural measures. Although planned for both the purpose of allowing timely evacuation of the floodplain and to limit property damage losses, the local systems are believed to have been economically justified on the basis of a reduction in property damages. Although the systems may be adequate for the purpose of evacuation (by providing flood threat recognition through their threshold alarm features), the property damage reduction benefits attributed to these systems are believed to be significantly overstated. The reason for this is due to major inadequacies in the addressing of the essential components of a flood warning and response system. The focus in implementing flood warning systems has been largely on only the hardware aspects and, in the case of Connecticut, its maintenance. Two critical areas in flood warning have been identified by the Corps as receiving insufficient attention. These areas are in the formulation of specific river stage forecasts, and in flood-specific preparedness planning.

It is believed that the forecasting of specific river stages is needed for purposes of property damage reduction since people are not likely to take mitigating actions in response to general flood forecasts. At present, three of the six local flood warning systems in New England do not have a flood forecasting mechanism. The reason for this lack of a forecast mechanism was investigated as part of the Corps work on the proposed system for Milford, since provision of a specific forecast for Milford was considered to be essential to obtain benefits. The apparent reason for the lack of a forecast mechanism for all systems is because of a lack of support of local flood warning systems by the National Weather Service (NWS), the Federal agency charged with the responsibility of forecasting floods. The resources of the NWS are apparently already stretched thin by their forecasting of floods for rivers with long lead times. The Eastern Regional Office of NWS has, therefore, developed a policy of supporting local flood warning systems only as time and resources permit. A forecast by NWS for these systems will not be guaranteed. NWS will, however, try to provide a manual forecast method that the local users, possibly with the state's assistance, will be able to use to prepare a river stage forecast. It is possible also that the void in forecast formulation can be filled by the private sector or others.

In addition, for most local flood warning systems, a pre-formulated response plan to use a warning does not exist. The purpose of the response plan is to "think through" the response to a flood forecast, and address actions which need to be taken. Insufficient resources to take these actions should also be identified and addressed. Through a plan, the response can be tailored to the forecasted severity of the flood. Emergency response planning, being a local matter, is typically out of the control of those implementing the systems.

The State of Connecticut is implementing a local flood warning system for the Wepawaug River in Milford, Connecticut for the purpose of reducing property damages. The local system, expected to be deployed in 1991, will include two precipitation gages, one combination lake level and precipitation gage, and one combination river stage and precipitation gage. All of these gages will remotely-report via radio waves to a monitoring base station computer located in a fire station in Milford. The local system's gages will also be monitored at computers at the state Department of Environmental Protection and NWS River Forecast Center that monitor Connecticut's statewide network of remote-reporting gages.

The ultimate success of Milford's system in reducing property damages is difficult to predict. The proposed flood warning system has several ingredients pointing to potential long-range success. The major ingredient is the state's support of the system since the local system will become a part of the statewide flood warning system. The state's support of the local system means that, in addition to assistance with initial funding of hardware costs, the maintenance of the remote hardware will be perpetually funded and performed by the state. The state will also provide personnel to monitor and assist with the local system, train the local system users, and maintain the software of the system. Because of its integration into Connecticut's statewide network, other uses of the remote-reporting hardware are expected to occur, thereby broadening the local system's base of support. Another factor that could bode long-range success of Milford's system is the fact that the base station computer will be equipped with software that supports fully-automated flood forecasting. The forecasting software, purchased in direct response to Corps concerns with the lack of guaranteed NWS support to Milford, will be tested and calibrated by the state, possibly with some NWS assistance.

The negative experiences demonstrated by other systems in New England may, however, be repeated. At present, emergency response personnel in Milford have expressed no interest in flood-specific response planning despite offers by the Corps to assist the City with its planning. Development of a flood-specific response plan is supposed to be a pre-requisite to state cost-sharing of the flood warning hardware, however. The lack of experience with the automated flood forecasting software, and the resulting specificity of a river stage forecast and warning time that could be provided, particularly in light of the rapid response of the basin to rainfall, could contribute to a system failure. The responsibility for formulating and issuing flood forecasts has not been clearly defined between the various entities. The Corps believes that Memorandums of Understanding between the city, the state, and NWS regarding river stage forecasting responsibilities are necessary to insure that a forecast is formulated and issued. A further potential barrier to successful system performance is the fact that flooding of the Wepawaug River is a rare occurence. Therefore, enthusiasm for emergency response planning for a flood that may occur in the future, and the annual updating of the planning needed to maximize system success, may wane.

In general it was found that there are several mis-conceptions with regards to local flood warning systems in New England. The successes of the systems appear more theoretical than demonstrated. Little science is evident in the design of flood warning systems. Automated flood warning systems do not, in most cases, result in automated forecasts as commonly believed; only the collection of the data is automated. The importance of all four components of a flood warning and response system is frequently misunderstood, and the considerable effort needed to address them adequately is, therefore, rarely expended.

The need for flood warning systems for purposes of saving lives and reducing injuries is not clear. More investigation needs to be conducted to determine the reasons for deaths and injuries. Are they due to inadequate warning, or are they due to a lack of common sense (such as by those who may chose water-based recreation during a flood)? Are there enough deaths and injuries to justify their widespread deployment?

The need for flood warning systems for the purpose of flood damage reduction is more clear. Deployment of flood warning and response systems for this purpose, however, must be carefully tailored to the stated purpose.

The Flood Plain Management Services program of the Corps can play a major part in flood warning and response system development and implementation. Experienced personnel in FPMS offices can evaluate the need for flood warning and response systems, the technical aspects of the systems, and the emergency response arrangements to utilize the warnings. Corps concerns regarding the major roles that private industry and local authorities play in a successful flood warning and response must be addressed, however, before a large FPMS role is played. Because the Corps cannot entirely control the efforts of the private and local entities, system success can never be guaranteed. The wisdom of putting the Corps stamp of approval on such systems is questioned.

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